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Laboratory simulation of karst on titan

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Abstract

Saturn's giant moon Titan has a landscape made of organic molecules, which is exposed to hydrocarbon-based rains, rivers, and lakes. Many of Titan's surface features could have resulted from dissolution, transport, and evaporite-formation of solid organic materials in a manner similar to dissolution/ evaporation processes on Earth. We have constructed an experimental apparatus using a fiber optic UV probe able to determine the rate of dissolution and the amount of material dissolved in hydrocarbon fluids at Titan's surface temperature of 94 K. For our initial work, benzene was selected as our proxy Titan organic molecule – there is spectral evidence that it exists on Titan's surface and has been detected in suprising amounts in Titan's upper atmosphere. Our initial results demonstrate that a ca. 10 mg sample of solid powdered benzene dissolves in 100 mL of ethane to its saturation equilibrium in about an hour at 94 K. The saturation equilibrium is 18 mg per L. This compares to the value of quartz in water at neutral pH (9 mg per L). It should be noted that the waters of the Roraima massif in Venezuela, one of the areas with the best developed solutional landforms in quartzite, have dissolved silica concentrations of less than 1 mg per L. While benzene was selected for initial laboratory investigation, there are other organic molecules on Titan that are predicted to have orders of magnitude higher solubility and higher abundance on the surface, notably acetylene and hydrogen cyanide. The solubility of acetylene in a methane/nitrogen Titan rainfall mixture at 95 K is predicted to be of the same magnitude as that of gypsum and water at 298 K (25 C). Our results provide laboratory evidence that supports the case for alkane-based dissolution geology on Titan.

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Laboratory Simulation of Karst on Titan

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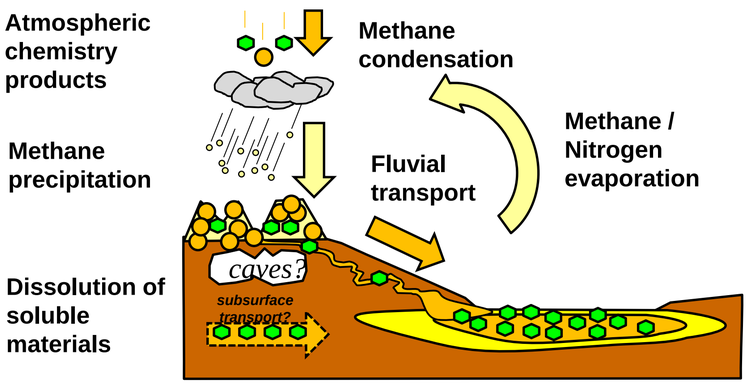
Can Titan organic materials dissolve in hydrocarbon solvents at 94 K? **Yes.**

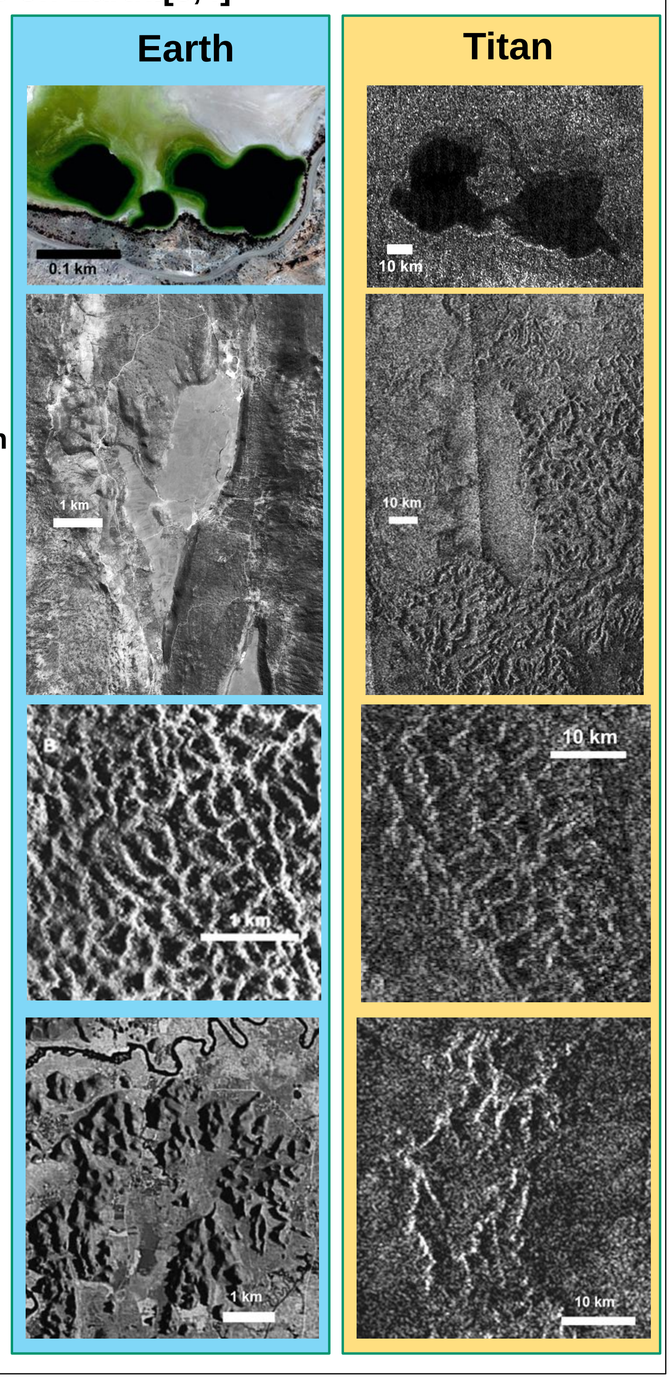
Background – Titan Organic Cycle

Saturn's moon Titan has an organic cycle based on hydrocarbon rains and organic photochemistry products (such as benzene) deposited on the surface.[1] Could it form karst?



Dissolution geology

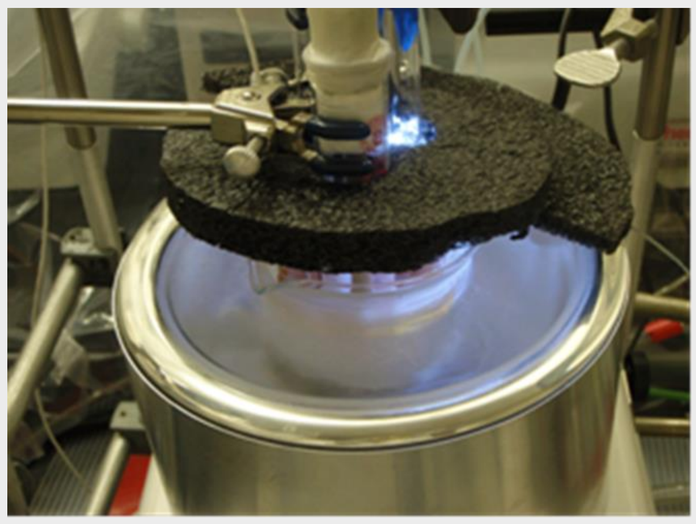
On Earth, water can dissolve soluble bedrock and create features called karst terrains.[2] Sinkholes are one example. Other examples include remnant towers, sinkholes, poljes, and corrosion plains. Many features on Titan look similar to karst terrains on Earth.[3,4]



Laboratory simulation

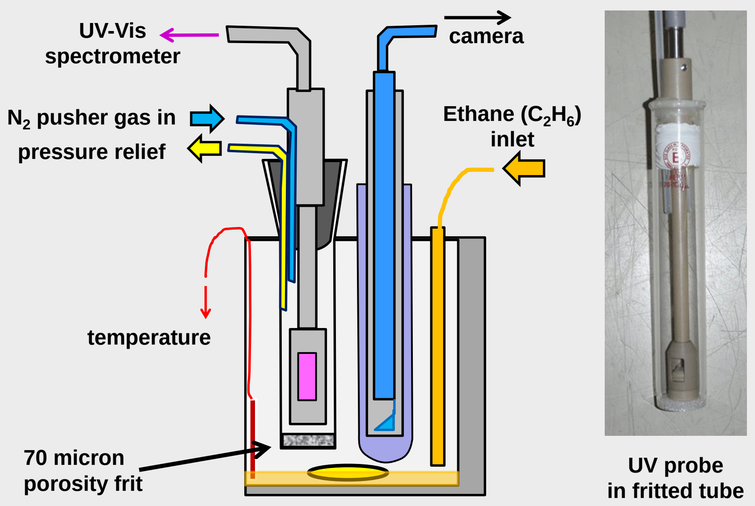
Determination of equilibrium concentrations and dissolution kinetics of Titan organics at cryogenic temperatures (94 K).

Experimental apparatus



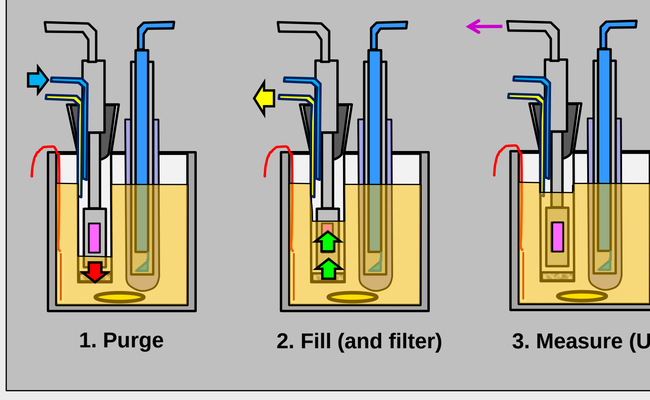
Experimental apparatus used to keep 100 mL ethane at 94 K under an N_2 atmosphere

Internal schematic



Operation

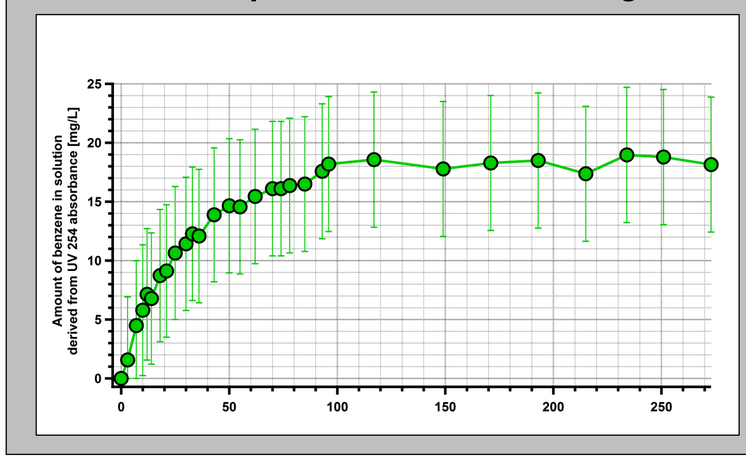
N_2 purge and refill of fritted tube and UV probe allows cryogenic filtration and measurement of solution



UV probe immersed in liquid ethane at 94 K

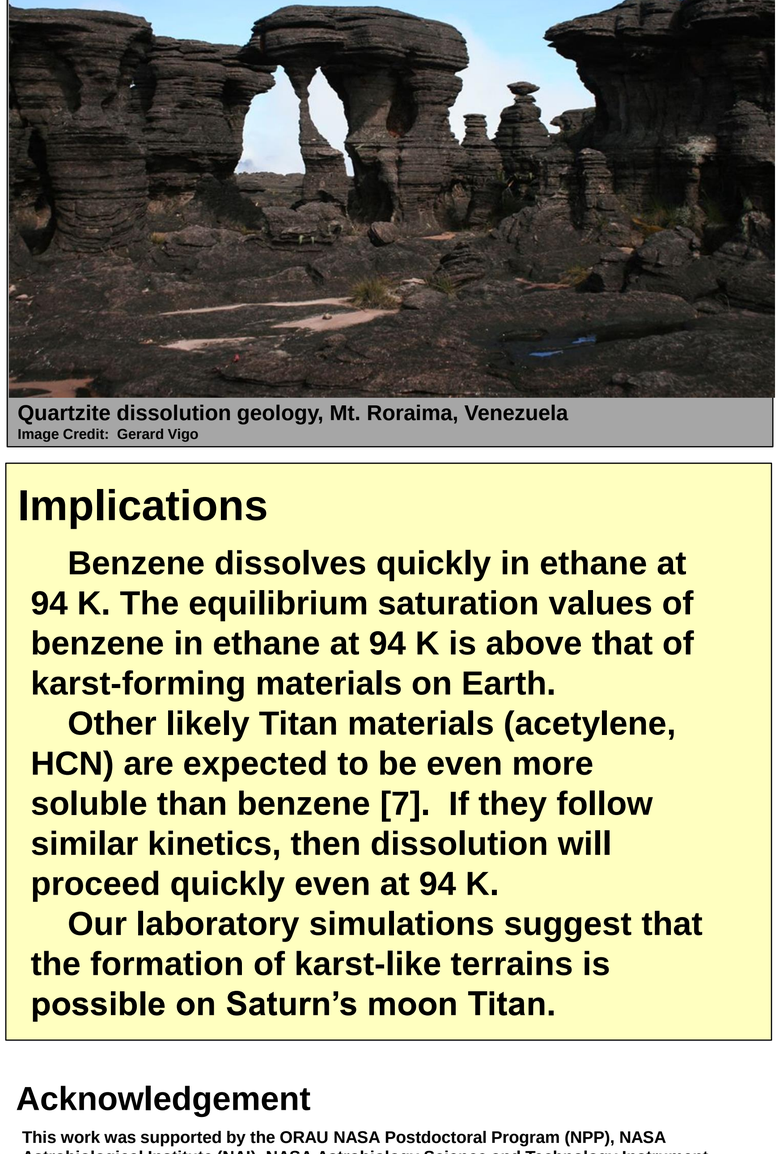
Results

Our UV absorbance data shows benzene quickly dissolves in ethane at 94 K. Saturation is reached in less than 2 h. Saturation equilibrium value: 18.5 mg / L



Comparision with Earth materials

On Earth, quartz has a saturation value in water of 9 mg / L [2]. Quartz can form karst terrains resulting from dissolution geology, such as the Mt. Roraima massif.[6]



Quartzite dissolution geology, Mt. Roraima, Venezuela
Image Credit: Gerard Vigo

Implications

Benzene dissolves quickly in ethane at 94 K. The equilibrium saturation values of benzene in ethane at 94 K is above that of karst-forming materials on Earth.

Other likely Titan materials (acetylene, HCN) are expected to be even more soluble than benzene [7]. If they follow similar kinetics, then dissolution will proceed quickly even at 94 K.

Our laboratory simulations suggest that the formation of karst-like terrains is possible on Saturn's moon Titan.

Acknowledgement

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